

HYDRO-ELECTRIC POWER STATION DESIGN

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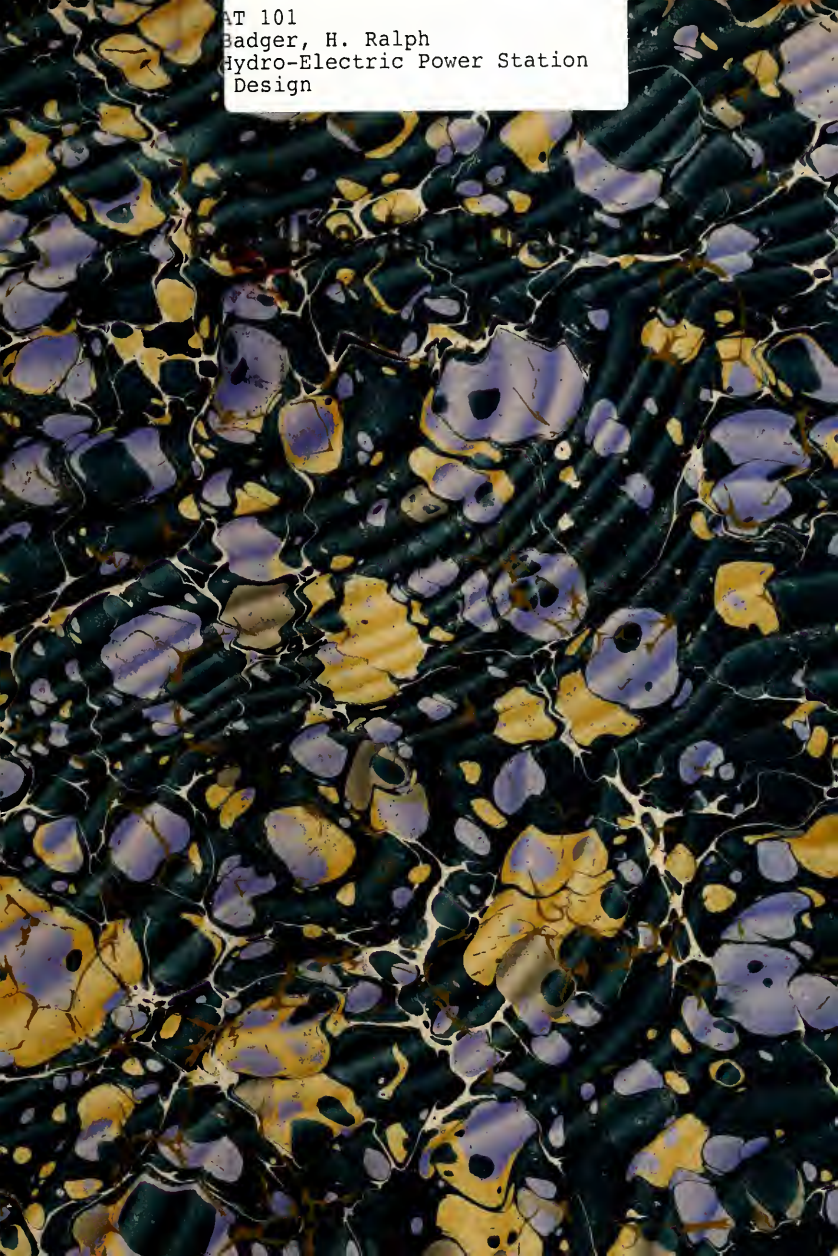
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Hydro-Electric Power Station
Design



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HYPER-ELECTRIC POWER STATION DESIGN

& THEORY

by

D. G. B. BROWN

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HYDRO-ELECTRIC POWER STATION DESIGN

A THESIS

PRESENTED BY

H. RALPH BADGER

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TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

1908

L. C. Morin,
Dean of Cultural Studies.

ILLINOIS INSTITUTE OF TECHNOLOGY
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J. M. Raymond
Dean of Eng. Studies

PREFACE.

The subject of "Hydro-Electric Power Station Design" has herein been presented in two parts :- the first - a brief treatise on the general principles and important factors, and the second - an application of these to a particular case.

In Part I. is given a general statement and analysis of the important factors entering into the design of such power generating stations.

In Part II. the actual design of a station for a particular location is undertaken. This proposed station to be located on the Snake River in the south-central part of the state of Idaho, and to receive its water supply from the Malad - a tributary of the Snake River.

H. R. B.
R. G. G.
H. W. N.

RESULTS

The results of the "three-figures" test are shown in Table I. The results are given in the form of the first - a table of the results of the test - and the second - a table of the results of the test, and the third - a table of the results of the test.

In Part I. is given a general statement and analysis of the results of the test, and the results of the test are given in the form of a table.

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Part I.

A Brief Treatise on the General Principles and Important Factors Enter- ing Into the Design of Hydro-Electric Power Generating Stations.

Hydro-Electric Power Station Design

Introduction.

A consideration of the subject of "Hydro-Electric Power Station Design" entails a discussion of the location of the market for sale of power, nature and extent of the water supply of the source of power, auxiliary construction for water handling, location, construction and equipment of generating station, transmission and distribution of energy.

The General Problem.

Electrical energy is now in nearly universal demand. The amount of this commodity that is made use of in any section of country varies within wide limits. For its common usages - in power and lighting - this variation is nearly directly with the population, though there is a constantly increasing demand for it in railway work - outside of centers of population. With the increased price of coal, as well as for other disadvantages inherent in steam production, - other means than indirectly from coal, of generating electric current,

Hydro-Electric Power Station Design

are being rapidly sought and utilized. Chief among these, in present importance, is the water power of natural sources.

As these cannot be located where wanted - as can steam plants - but must be taken where found, the general problem becomes one of relation between location of market for power and the source of power generation. Ordinary commercial principles would usually dictate that a power development be carried forward only after a demand had arisen for power in a given locality. This is merely a creation of supply to meet demand. There have been, however, in recent water power developments - numerous cases of the opposite procedure to this. In such projects, water powers - especially favored by location or proportion or both - have been developed first and the market created afterwards, in range of transmission. This constitutes a forcing demand in such localities - by the creation of an attractive supply.

Hydro-Electric Power Station Design

are being made by the power and utility companies. These, in turn, are being passed on to the water power of

Natural sources.

As these are not located where water is

can steam plants - but must be taken where found,

the general problem is one of location of power. Location of plants for power and the location of power

an expenditure. Ordinary commercial production

would usually estimate that a power development is

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power in a given location. This is usually a

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located in power water power development - this

was one of the objects of the study. In

when hydro-electric power is developed - this is usually

by location or production of power - this is usually

developed first and the power is then developed

in terms of power. This is usually a

city power in such locations - this is usually

of an extensive study.

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The allowable distance between the point of generation of power and the point of consumption is therefore limited by the range of economic and safe transmission of the energy. As a result of improving methods and equipment this distance is gradually lengthening. Present practice does not much exceed one hundred miles for this as a maximum figure.

Outside of matters of relative location of market for power and the source of power supply, there are several important points to be considered under the "general problem". First among these arises the question of the ability of the water supply to satisfy the market for power; that is, whether the maximum continuous hydraulic power of the source is sufficient to meet the demands of the market. The assumption is made that the "water rights" for this amount are obtainable. If the amount of hydraulic power thus covered is not sufficient, then the advisability or necessity of

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an auxiliary steam plant must be considered. Next comes a consideration of the character of the load. That is, the purpose for which the power is to be used,-- whether for lighting, for railway work, for miscellaneous power purposes or for a combination of these. If the latter, then the approximate proportion of each.

All of these points must be reviewed under a general survey of a water power development. For further consideration, the more detailed factors influencing a project must be taken up. These are outlined in what follows.

The Water Supply.

The very existence of a hydro-electric power generating station depends upon its water supply. Obviously then, the continuity and comparative uniformity of flow of this should be at least reasonably assured.

Power sources, for such developments, at present are chiefly confined to the fall and flow of

An auxiliary steam plant will be considered. Next
 about a consideration of the character of the load
 that is, the purpose for which the power is to be
 used—whether for lighting, for railway work, for
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The Water Supply.

The very existence of a hydro-electric power
 generation depends upon the water supply.
 Obviously then, the continuity and constancy of
 volume of flow of this supply is of great impor-
 tance.

Power works for the development of a
 plant are directly connected to the flow of

Hydro-Electric Power Station Design

streams. The two main factors governing these developments are the "head" and the volume. The first quantity represents the difference in elevation between the surface of the water in the supply reservoir and in the tailrace: that is, the difference in height of the water before and after its potential energy has been utilized. This factor is commonly given in "feet." The second quantity is the flow, or volume of water per unit of time which is available for use at the given head. This factor is usually expressed in "second-feet"- an abbreviated expression for "cubic feet per second".

The available head, for any project, is -once it has been decided upon - practically constant. It may be ascertained by means of a careful topographic survey of the stream. On the other hand, however, the second factor - namely the "flow" - is, owing to the variable quantities upon which it depends,- quite likely to be anything but constant. It is this factor which gives rise to most of the difficulties to be met in hydro-electric power sta-

Hydro-Electric Power Station Design

tion work.

A more careful investigation into the nature of this quantity - "flow" - will reveal the fact that it ^{is} liable to change from day to day, season to season and even from year to year. Primarily, it depends upon the size, contour, vegetation and soil of the drainage area of the stream, as well as upon such climatic conditions as rainfall, temperature and barometric pressure. In the calculation of this quantity both the greatest care and the most conservative judgement should be used. Even with these detailed precautions, unusual conditions may arise at times, after the project is completely installed, - conditions of great excess, or the exact opposite, in the water supply. The result being that a large proportion of the investment, possibly the entire amount, will be rendered valueless. Such serious happenings have been known to take place and nothing should be left undone in the way of precaution. Therefore all records that it is possible to obtain of the

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A more careful investigation of the nature of this material - "flow" - will reveal the fact that it is liable to change from day to day, season to season and even from year to year. Particularly it follows that the size, content, composition and color of the material will be different in different seasons. In the spring and summer the material is usually of a light color and contains a large amount of water. In the autumn and winter it is usually of a dark color and contains a small amount of water. The material is also liable to change in composition and color from one place to another. In the spring and summer it is usually of a light color and contains a large amount of water. In the autumn and winter it is usually of a dark color and contains a small amount of water. The material is also liable to change in composition and color from one place to another.

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flow of the stream in question should be carefully examined and compared, as well as careful attention paid to all of the factors influencing it. The object of such researches throughout, being to obtain as accurately as possible, first - the actual minimum that can be reasonably expected from the stream in point of constant flow, and second, the points of maximum discharge - together with means of conserving the energy of such surpluses of water.

Foremost to be considered is the drainage area. This should be investigated from the source of the stream and its tributaries to its mouth. Area, contour, vegetation, soil and rainfall should be considered. Other factors the same, the larger the area drained, the greater the "run-off" of water. The contour, vegetation and soil manifestly influence such quantities as absorption of rainfall and the evaporation of surface waters - with a subsequent influence exerted on the resulting "run-off". The effect of rainfall on stream flow is positive though not absolute, as it is greatly

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affected by the above outlined climatic conditions. The dry-weather flow of a stream is not so much influenced by the total annual rainfall as it is by the distribution of such rainfall as occurs throughout the year. In this case, as in all cases of relation of rainfall to stream flow, no absolute and general rule can be formulated, the problem of each watershed being distinctive. However, there are some considerations common to all cases and these will be here briefly taken up.

In the first place, what may be termed the "water year", begins approximately with the month of December and ends approximately with the November following. This is divided into three periods: the first six months constituting the "storage" period, the next three months - the "growing" period, and the remaining three months - the "replenishing" period. During the first period the winter snow and the spring rains saturate the ground to a considerable depth, a large amount of water being held in storage in lakes, swamps and forests as

and the fact that the Government has been unable to secure the necessary funds to carry out its policy of non-interference in the internal affairs of other countries. The Government has been unable to secure the necessary funds to carry out its policy of non-interference in the internal affairs of other countries. The Government has been unable to secure the necessary funds to carry out its policy of non-interference in the internal affairs of other countries.

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well as in the soils, gravels etc. At this time in the year a heavy rainfall finds a quick response in large stream flow, for the saturated ground rejects further water, and the water runs rapidly from the surface. That part of the stored water of this period which lies above the level of the bed of the stream, within the boundaries of its watershed, becomes available for supplying the stream as well as for the purposes of surface evaporation and the sustaining of plant life. These waters will supply a certain part thereof to the stream, regardless of the rainfall, even maintaining a flow in the stream for some months without any rainfall.

During the "growing" period the ground water furnishes practically the entire supply to the flow of the stream, the only additional part coming from an occasional rainstorm. In some cases so depleted does the ground water become by the end of August that even a very heavy rain will make no perceptible difference in the stream flow, the

well as in the turbine, however, the latter time in the year a heavy rainfall finds a quick response in large stream flow, for the retention of water in the reservoir, and the water runs rapidly from the surface. Thus part of the stored water in this period which flows down the front of the bed of the stream, within the boundaries of the water shed, however, supplies for the turbine as well as to the demands of agriculture and the sustaining of plant life. These waters will supply a certain part of the demand of the stream, regardless of the rainfall, when obtaining a flow in the stream for some months without any rainfall.

During the "drought", when the ground water supplies are depleted the entire supply to the turbine of the stream, the only additional part coming from an artificial reservoir. In some cases the depletion of the ground water is so great that it is necessary to draw from a very deep well, or of larger diameter in the stream bed, the

Hydro-Electric Power Station Design

ground absorbing the entire amount of the precipitation.

During September, October and November the ground begins to receive its store of water, and with favorable rainfalls, it becomes saturated during the "storage" period following. The stream flow is a constant drain on this supply, but in addition to this, there is a loss of water falling on the watershed due first to evaporation and second to that amount taken up by plant life.

Having thus discussed the subject of Drainage Area and the influence of its various components on stream flow, we come to a consideration of the stream itself. No matter what the more or less theoretical factors influencing the stream flow may be, we have finally to deal directly with the actual volume of water flowing in the stream. To measure this quantity there are three general methods, any one of which may be used: the choice, in any case, depending upon local conditions, the degree of accuracy desired, the funds available, and the length

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of time that the record is to be continued.

The first general field method for obtaining the value of stream flow is by measurement of the slope and cross section and the use of Chezy's and Kutter's formulas: the second method is by means of a weir: and, the third by measurement of the velocity of the current and the area of cross section of the stream. Where conditions will permit, the second method offers the best facilities for determining the flow.

The greater the period of time for which this data is available,-- showing past performances of the stream under various conditions of season and climate-- the more accurately can its future probable flow be predicted. As it is with this quantity of "future flow" that the proposed plant will have to reckon, calculations for it should, if possible, be based on data for at least a number of consecutive years previous.

A very convenient way of considering this is

of time that the record is to be continued.

The first general field method for determining

the value of stream flow is by measurement of the slope and cross-section of the stream bed and the use of Chezy's formula.

Chezy's formula: the velocity of flow is proportional to the

of a water: and, the third is measurement of the

velocity of the current and the use of some form of

tion of the stream. Where conditions will permit,

the section should be taken the best possible for

determining the flow.

"The greatest difficulty of this method is that

data is required, - namely past performance of

the stream under various conditions of water and

climate - the more accurately the future performance

able flow be predicted. As it is with this method

ty of "future flow" that the proposed plant will

have to rely on, calculations for its output, if not

alone, be based on data for at least a number of

consecutive years previous.

A very convenient way of conducting this work is

Hydro-Electric Power Station Design

to plot, for each year upon which data is available, a curve showing the relation between the time of the year and the flow. The abscissae represent the days of the year, division points locating the different months, and the ordinates - the corresponding flow in "second-feet". A scale of theoretical hydraulic horse power may be marked off on the axis of ordinates, this merely representing a constant times the "second-feet" of flow,- the constant depending upon the "head" and the weight of water. From this scale may be read directly the power possibilities of the stream at any given time. A straight line drawn parallel to the axis of abscissae through the lowest point on the curve, will show the maximum power to be realized from the stream throughout the year. If the physical conditions of the channel and banks of the stream will permit of the construction of a properly proportioned dam together with retaining walls (if necessary), then the whole or at least a part of the water represented by the "peaks" on the time-flow curves may be

to first, for some years when which said in 1910-11
 a survey showed the relative between the size of
 the year and the flow. The following represents
 the data of the year, division points, location, the
 distance, month, and the condition - the distance
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 evidence, which shows that the water is not only
 of ordinary, but the water is not only a constant
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stored up as "pondage", and drawn off at times of "low water", the resulting maximum constant flow being thus increased. The comparison of the time-flow curves for a number of years, on the same stream, will show the variation to expect - at least as possibilities- from year to year.

From a proper consideration ,then, of the foregoing points - influencing the water supply of a hydro-electric development - may be obtained a fair calculation of the power to be expected from the source. From this, we are lead to a consideration of the exact location of the plant.

Exact Location For Plant.

The approximate location of a hydro-electric project being determined by means of the factors of the "General Problem", namely the market for sale of the energy and the source of the water power, there remain but a few points which will decide the exact location of the plant.

The question of "water rights" must be settle

Hydro-Electric Power Water Control

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flow control for a number of years, and the water control

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calculation of the power to be expected from the

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of the exact location of the plant.

Exact Location of Plant

The exact location of a plant is

project being determined by means of the location

of the "control project", and the control of

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The question of "water control" is the

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By this is meant the obtaining from the State of the right to use, for power generating purposes, a certain number of second-feet of water from the stream in question. After this, comes the matter of real estate on which to locate the power house and auxiliary water controlling works. This is, however, usually a minor point as such property is generally some distance from centers of population, and hence its value is comparatively small.

Outside of these considerations, the exact location of the plant should be such as to realize the greatest efficiency from the two controlling factors in any project, namely the "head" and the volume of water. The most available head, considering total fall and the possibilities of back-water, and the arrangement permitting of the most economic use of the volume of the water, considering the desirability or necessity of storage supply - are the two factors to be sought. With this decided we pass to a discussion of the component parts of a

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hydro-electric power generating project.

Parts of the Project.

With the exact location of the plant settled, the general lay-out of the auxiliary water controlling works must be determined upon. The devices best adapted to conveying the water from the source of supply to the wheels - form a question peculiar to each individual case. However, they consist - in general - of a reservoir, either a part of the stream or apart from it; a conducting pipe-line from this to the power house, or in the case of an open penstock type - a forebay; and, a tail-race. In this work, such parts as dams, intakes, penstocks gates and tail-races must be considered, and are here treated of briefly.

Dams.

For water-power work, there are two kinds of dams most used - depending upon the material of their construction, the first - the earthen, and the second - the masonry dam. Of these two classes

Werner-Heinrich Power Station (cont.)

Power of the Project

With the above location, the plant will

the normal level of the water in the reservoir.

The power will be determined by the

best suited to the project the water in the reservoir

of water to the power - from a reservoir

to each individual unit. However, the power

in general - of a reservoir, either a part of the

stream or part of it; a reservoir

The water in the power house, or in the case of an

open reservoir, the water is a reservoir

In this case the power is determined by the

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the failures of earthen dams have been the most numerous, the cause being either that there was not the proper length of spillway, or that the outlet pipes were not properly laid in the dam. The requirements for stability of any dam are, that it be strong enough to withstand the pressure of all water that it holds back, that it withstand leaks, and that it afford proper spillways and sluice-gates.

In the construction of an earthen dam, three things must be considered: first, the conditions must be such that the maximum flood that has ever occurred at the site can be taken care of during the building of the dam; second - the water must never top the embankment of the dam, - it being either led around the end of the dam or through some new channel; third - the proper soil should be used in the construction of the dam. If conditions are such that the flood waters likely to arise cannot be carried around the end of the dam during its construction, then the earthen dam should never be

The entrance of water into the main
 chamber, the water being allowed to flow
 the proper length of spillway, or that the outlet
 pipes were not properly laid in the dam. The pos-
 sibilities for leakage of any kind and that it is
 strong enough to withstand the pressure of all vi-
 ces that it might have, that it will not be broken
 that it is not proper spillway and outlet pipes.
 In the construction of an outlet pipe, care
 things must be considered: First, the outlet pipe
 must be made with the outlet pipe that the water
 occurred at the side and be taken care of during
 the building of the dam; second - the outlet pipe must be
 very top and bottom of the dam - it being al-
 lowed around the end of the dam in length, it is
 outlet; third - the outlet pipe should be made
 in the construction of the dam. It is essential
 such that the flood water is liable to enter outlet
 be carried around the end of the dam during the
 construction, that the outlet pipe should be set to

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used.

Any soil used in the construction of an earthen dam should be tested for quicksand, and if any traces are found the soil should be discarded. Soils having an angle of repose of less than twenty degrees when placed in water should not be used. The best soils for use are those containing enough clay to give the required water-tightness and binding quality,- too much of this ingredient should be avoided as it swells on becoming wet and shrinks on drying. If, during the construction the materials are dampened, cracks and leaks are less liable to occur. If the material at hand is of different grades, the best should be placed on the upstream side, gradually changing to the more porous toward the center of the construction.

The profile of an earthen dam will depend upon the height of the dam. The slopes will depend upon the angle of repose of the material used, it being usual to make the inner or upstream side

• 25/11/2019

Any soil used in the construction of an embankment should be tested for thickness, and if any traces are found the soil should be discarded. Soils having an angle of repose of less than twenty degrees when placed in water should not be used. The best soils for use are those containing enough clay to give the required water-tightness and being of good quality - see Table of this ingredient should be avoided as it settles on becoming wet and settles on drying. In testing the composition, the water-tables are determined, and the soil is found to be of good quality. If the material is found to be of good quality, the best should be used in the construction of the embankment. The material should be tested for water-tightness, and the water-tables are determined, and the soil is found to be of good quality. If the material is found to be of good quality, the best should be used in the construction of the embankment.

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flatter than the outer or downstream side, as earth when wet has a flatter slope than when dry.

Where a masonry dam is constructed, more attention must be paid to the foundation than is necessary in the case of an earthen dam as any settling of the masonry will cause cracks. With high masonry dams the foundations are usually made of solid rock. The superiority of the masonry over the earthen dam lies in the facts that it can be made more durable, can be more precisely designed, and better protected from flood waters, owing to the safer construction it offers for the laying of the outlet pipes. For all dams of any height, masonry construction is to be preferred.

The shape of a masonry dam will depend upon the head of water for which it is designed, for low dams the cross-sectional shape usually being trapezoidal, but for high heads the sides are usually curved for the purpose of saving material.

The reinforced concrete dam has some advantages

flatter than the outer or downstream side, as shown
which was a flatter slope than the other.

where a heavy dam is constructed with a

flatter slope to the foundation, there is a heavy

any in the case of an earthen dam as well as in

of the dam will cause a heavy. With high water-

ry dam the foundation is not in the case of earth

rock. The superiority of the heavy over the ear-

on dam lies in the fact that it can be made more

thrust, can be more readily designed, and better

protected from flood waves, owing to the better

construction it offers for the laying of the outlet

pipes. For all kinds of high water, heavy concrete

than in to be preferred.

"The shape of a heavy dam will depend upon

the head of water for which it is designed, but for

down the cross-sectional shape is usually water resis-

tional, but for heavy dams the shape is usually

designed for the purpose of saving material.

The reinforced concrete dam has some advantages

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that the masonry dam does not possess. It can be made more stable than a masonry dam of the same dimensions. The materials can be distributed to better advantage and therefore there will be a saving in cost. The interior of the dam can be inspected, it can be constructed more rapidly and does not require such good foundations as do masonry dams. In many cases where a reinforced concrete dam is constructed the power house is built into the dam, thus greatly reducing the cost of the project.

One factor in the building of concrete and masonry dams which does not affect the earthen dam is the effect of ice. In countries having cold winters the expansion of ice is liable to be great enough to rupture the dam, masonry more so than concrete.

"Intakes" lead from the dam, being either submerged or at the level of the water. The flow through them being controlled by gates which are either machine or manually operated.

that the majority of the population is not
made more stable than a few years ago and the
remains. The majority of the population is not
any advantage and therefore there will be a
in fact. The interest of the population is not
it can be considered as a very high and not
during such good conditions as the majority of
when there is a reinforced structure and is con-
structed in fact with the help of the
thus greatly reducing the cost of the project.

The fact is that the building of concrete and

massive steel does not affect the structure
is the effect of the. In countries like Italy
within the explanation of the building of the
enough to reduce the cost of the building
concrete.

"In fact, I am from the fact, which is the

period of the level of the water. The flow
the fact that the building of the water which
either the fact or the fact of the

Hydro-Electric Power Station Design

Penstocks.

The cheapest form of penstock is the circular wooden stave penstock. The staves should be as free from knots as possible and should be smoothed on the inside in order to reduce friction and get the maximum efficiency. Where the stave penstock is installed it is common to have all bends and curves in the line of steel pipe, unless the curve be of large radius. Iron hoops or bands are used to hold the staves in place, their spacing depending upon the initial tension, the water pressure, and the swelling of the wood.

Steel penstocks are especially adapted to long pipe lines, as often, in such lines, abnormal pressures are developed due to the sudden shutting-off of the water from the turbines. In order to regulate this pressure, a small reservoir is constructed at the outlet of the penstock, the size of this reservoir depending upon the time it takes to close the turbine gates. In place of the reservoir

Hydro-Electric Power Station Design

a steel standpipe is sometimes used, the water running over the top of the standpipe if the gates be closed too suddenly. If the fall of the pipeline be too great for standpipes, safety valves are placed along the line of the penstock. The life of a steel penstock is sometimes very short due to the rusting of the steel, though this action may be greatly reduced by treating the penstock with hot asphaltum. At the entrance to penstocks, racks should be so placed as to collect all floating objects and not allow them to pass into the pipe. In cases of ice formation these racks may become clogged if the ice is not removed on forming. A large, deep forebay will remedy this trouble, as the water, being quiet here, will freeze over at the beginning of cold weather. Then such anchor ice, as may come into the forebay, will rise to this layer of ice, while the warmer water will circulate below. If the intake to the penstocks be so located as to receive this water, there will be little trouble from ice at the racks.

a steel structure is necessary, the steel must
 be set over the top of the structure and the steel
 must be anchored. At the top of the structure
 be too great for steel, and the steel must be
 along the line of the structure. The line of
 steel structure is necessary for the steel
 setting of the steel, and the steel must be
 and the steel must be anchored. At the top of
 should be as close as possible to the structure
 and the steel must be anchored. At the top of
 in case of the structure and the steel must
 closed if the ice is not removed in time. A
 large, and the steel must be anchored, as the
 water, and the steel must be anchored, as the
 standing of the water. The steel must be
 may be too great for the steel, and the steel
 of ice, and the water must be anchored. At
 in the future the steel must be anchored as
 receive this water, and the steel must be

Hydro-Electric Power Station Design

Tail-race.

This should be deep, as it is necessary to have dead water in the race before the wheels are started. As soon as water is discharged from the wheels this will take the place of dead water and thus there will be no resulting loss of head. It is usually necessary to place the wheels at some height above the tail-race, the water after leaving the wheel passing through a draft tube. This draft tube should be air tight and submerged - at its lower end - in the water of the tail-race to prevent any loss in head.

Power House Equipment.

Water Wheels.

These may at once be divided into two classes - impulse wheels and turbines. The former is typified by the Pelton Company's wheel, in which the velocity of a jet of water impinging tangentially upon a disc, carrying buckets around its periphery, transmits to the buckets a part of its velocity.

100-100-100

This should be done, as it is necessary to keep the
dead water in the tank below the wheels and to keep
the water in the tank as soon as water is discharged from the wheels.
This will take the place of dead water in the tank
there will be no regaining loss of water. It is neces-
sarily necessary to keep the wheels at such a height
above the water level, the water after leaving the
wheel passes through a small tube. This tube
tube should be set right in the water - at the same
or end - in the water of the tank to prevent
any loss in head.

• *Staphylococcus aureus* – 30-40% of cases

... ..

These may be once be divided into two classes: (1) those which are used for the purpose of lifting the vessel, and (2) those which are used for the purpose of moving the vessel. The former are divided into two classes: (a) those which are used for the purpose of lifting the vessel, and (b) those which are used for the purpose of moving the vessel. The latter are divided into two classes: (c) those which are used for the purpose of lifting the vessel, and (d) those which are used for the purpose of moving the vessel.

Hydro-Electric Power Station Design

It can be shown that the efficiency of the transformation is a maximum when the velocity of the moving buckets is one half that of the jet, so that if H is the effective head of the source, for maximum efficiency, the peripheral velocity of the wheel is related to the head by the expression:

$$v' = .5 \sqrt{g H}$$

and the head being assumed invariable, it is seen that for a certain definite speed (imposed by the frequency of the generator), the only variable is the diameter of the wheel and this may be adjusted, within certain limits, to conform to the relation above. Thus direct connection of the generator to the source of power is possible, which eliminate the losses in transmission through gearing and the noise incident to its use.

These wheels require that there be sufficient distance between the wheel and the highest point of backwater, to allow for the discharge of the spent water from the buckets of the apparatus, and for

It can be shown that the efficiency of the turbine formation is a maximum when the velocity of the water in the buckets is one half that of the wheel, and that the effective head of the turbine, the velocity of the wheel is related to the head by the expression:

$$V = \sqrt{2gH}$$

and the head being assumed constant, it is seen that for a certain bucket speed (expressed by the frequency of the generator), the only variable is the diameter of the wheel and this may be adjusted within certain limits, to conform to the relation above. When these conditions of the generator to the turbine are met, the turbine will operate at the most efficient point, and the losses in transmission of power will be at a minimum. The losses in transmission of power will be at a minimum when the turbine is operated at the most efficient point, and the losses in transmission of power will be at a minimum when the turbine is operated at the most efficient point.

These results indicate that there is a definite distance between the wheel and the generator, and that the distance between the wheel and the generator is a function of the diameter of the wheel, and the diameter of the wheel is a function of the diameter of the wheel, and the diameter of the wheel is a function of the diameter of the wheel.

Hydro-Electric Power Station Design

a variable height of back water at different seasons of the year, this involves a serious loss of head. Also, since the action of the machine depend upon the velocity of the jet, which in turn depends on the square root of the head, the Pelton wheel is only available with any great efficiency when the head is great, i.e. above three hundred feet. In general, then, its use should not be considered with heads less than this.

Water turbines are available for the lower heads, since they do not depend entirely upon the velocity for the necessary kinetic energy - the large mass of water obtained may reduce the necessary velocity. These machines are typified by the products of the James Leffel Co., the S.Morgan Smi Co. and many others. Under favorable conditions they give an efficiency of from eighty to eighty-two percent, and may be obtained in the horizontal or verticle form. The verticle type, on account of the reduced friction losses caused by the lessened friction in the bearings, gives an efficiency

a variable height of water within at different times of the year, this condition is also to be considered. Also, since the action of the water depends upon the velocity of the jet, which in turn depends on the square root of the head, the velocity itself is only available with any given efficiency when the head is great, i.e. where there is a large fall. In general, then, the head should not be considered with heads less than this.

When finding the available power for the lower needs, since they do not depend directly upon the velocity for the necessary kinetic energy - the large mass of water contained in the reservoir is the important factor. These conditions are to be taken into consideration of the head itself, the velocity, etc. and many others. Under favorable conditions they give an efficiency of from thirty to thirty-two percent, and may be obtained in the horizontal or vertical form. The vertical type, on account of the reduced friction losses caused by the lessened friction in the passage, gives an efficiency

Hydro-Electric Power Station Design

about three per cent higher than the horizontal type, exclusive of gearing, but due to the fact that gearing is necessary to change the direction of motion, involving a loss of about ten percent, the actual net efficiency is reduced approximately seven percent unless the generators are of the vertical type also. Horizontal wheels are favored because they permit the use of several units on one shaft, and if this number is even, the unbalance of pressure caused by one unit is taken up by the next so that the friction loss is diminished. In order that vertical units may actuate one shaft, this shaft must be horizontal to conform to practical conditions and the use of vertical generators as was noted above, is precluded, and there is also introduced the loss due to the gearing which must be installed.

In choice of prime movers it is therefore necessary to consider:—

1. The available head, which will determine practically the availability of Pelton or turbine

about three per cent higher than the horizontal type, exclusive of a guide, but due to the fact that bearing is necessary to carry the reaction of motion, involving a loss of about ten percent, the actual net efficiency is reduced approximately seven percent unless the reactions are of the vertical type also. Horizontal wheels are favored

because they require the use of external units on one shaft, and in this respect is better, the unbalanced of pressure caused by one half is taken up by the rest so that the friction loss is diminished. In order that vertical and the low water one shaft, this unit must be horizontal to coming to practical conditions and the use of vertical reactance as was noted above, is indicated, and there is also introduced the loss due to the bearing which must be installed.

In choice of type of power it is therefore

necessary to consider:—

1. The available head, which will determine practically the availability of friction or slipping

Hydro-Electric Power Station Design

wheels by the condition that for heads above three hundred feet the Pelton wheel is to be preferred, for heads less than two hundred feet, the turbine, and for intermediate heads, either one indifferently.

2. The type and speed of the units and their capacity, since for generators of large size it may be necessary to install several units on one shaft, which involves the difficulty mentioned above, and the ¹restrictions that limit the generators of the horizontal type.

3. In addition to these conditions, which must hold generally, others are imposed when the head is not constant, that is, when the backwater is variable. In this case the velocity of the wheels will not be constant, and since the generators are practically constructed to operate at a constant frequency, this variation could not be allowed, even if the field rheostat of the machine were capable of taking up the increase or decrease of pressure ^aat the terminals. Also, since a decrease in speed will decrease the output, it would be necessary,

Wheels of the transmission belt for power station three
 running. Each side belt wheel is to be mounted on
 the shafts of the two horizontal feet, the bearings
 and the intermediate bearings, either one horizontally.

2. The type and number of the units and their
 capacity, also the number of large and small
 of capacity, to be used in each unit on one shaft,
 which will be directly connected to the
 the transmission belt and the bearings of the
 horizontal feet.

3. In addition to these conditions, which
 must be met, others are required when the
 head is not constant, that is, when the bearing
 is variable. In this case the variation of the wheels
 will not be constant, and since the bearings are
 generally considered to be constant in a constant
 transmission, this variation must not be allowed, and
 if the shafts of the bearings were capable
 of taking in the increase or decrease of pressure
 at the bearings. Also, since a constant is required
 will increase the output, it will be required.

Hydro-Electric Power Station Design

even in the above case, to install a greater capacity than would be required at the normal full-load speed and the disadvantages noted would still be present.

In this case it is necessary to install another wheel ^{which} is geared with a higher ratio to the line shafting so that when the head is decreased this wheel may be thrown in with the other one, their speed then being a mean between the two and the decrease in output of the first being supplied by the second. If the variations in head are very wide, it may be necessary to install several of these additional wheels and allow them to run idle during the normal operation of the plant. This extra installation of course involves a higher first cost and is to be avoided if possible.

In the choice of the number of units there should be considered the over load capacity of the units so that when one is disabled or shut down the remainder of the plant may carry the load without exceeding the allowable overload rating of each

Hydro-Electric Power Station Design

unit. It is common practice to decide on this rating as 88%, and it then follows that four units are necessary since one may then be cut out and the rest can carry 33% overload and maintain the normal output of the plant.

Generators:— The first classification of generators is into the direct and alternating current machines, and the choice is determined by the character of the load and the transmission distance. We assume that this distance is not short enough to warrant the use of direct current, and proceed to consider the features which determine the choice of alternators. The problem for direct current transmission is much simpler, and may be solved by neglecting the factor of frequency.

The conditions determining the frequency are the character of the load and the transmission; for example if the power is to be supplied to synchronous converters the frequency should not exceed forty cycles, and to conform to the apparatus already in stock in the manufacturing concerns, this figure should probably be chosen at twenty-five.

Unit. It is common practice to transfer the unit
ing as 33%, and it then follows that the unit
and necessary since on the unit the unit
that can carry the weight of the unit
the unit of the plant.

General remarks: The plant is a unit of the
system is into the direct and indirect system
system, and the system is determined by the direct
order of the load and the transmission system.
The system is not a unit of the system
to transfer the use of direct system, and the system
to transfer the system which is not a unit of the system
of electricity. The system is not a unit of the system
transmission system, and the system is not a unit of the system
by electricity and the system of electricity.

The conditions of the system are the system and
the character of the load and the transmission;
the system is the system is to be applied to
the system of the system is the system of the system
and the system of the system, and the system of the system
system is not in the system of the system,
this system is not in the system of the system.

Hydro-Electric Power Station Design

This is also suitable for transmission and power service, but has the disadvantage that incandescent lamps do not operate well at this frequency so that if the lighting load is not concentrated in cities where it may be supplied by synchronous converters it may be necessary to install frequency changers. At sixty cycles this difficulty would be avoided, but converters do not operate at this frequency with any great stability, and the conditions of constancy of service demand that the substation operation be as nearly perfect as possible.

If it is found desirable to use this higher frequency, induction motor-driven generators may be installed for the conversion to direct current, but this eliminates the possibility of compensation for lagging current in the line, and this difficulty may be of considerable magnitude if the line is to supply power to induction motors along the right of way.

A careful consideration of the load to be supplied will therefore be necessary in order to determine the frequency at which the current is to be supplied.

Hydro-Electric Power Station Design

The voltage to be generated by the machines is of little importance if it is to be stepped up for transmission, so that this fact must be determined. The highest voltage at which it is practicable to generate is about 11,000. In deciding upon the transmission voltage it is common practice to figure roughly upon a thousand volts per mile within the limits of safety, which is set at 80,000 volts in this country. We therefore decide that if the distance to which power is to be transmitted exceeds ten or fifteen miles it will be desirable to step up the pressure and generate at such a potential that the insulation of the machines will not be in danger nor will the armature be forced to carry excessive current.

It having been decided in the preliminary investigation what will be the capacity of the plant, the next step is the division of units. The same conditions which govern the number of prime movers apply here and we may state that there should be at least four units, a greater number being of course necessary when the output of the plant is so great

High-Frequency Power Section Design

The voltage to be generated by the circuit is

is a little higher than that of the standard

for comparison, so that this fact must be taken

into account. The highest voltage at which it is possible

able to generate is about 15,000. In this case you

the standard voltage is 15,000, which is

three times upon a standard voltage of 5,000

within the limits of safety, which is set at 25,000

voltage in this country. We therefore desire to

in the future to which power is to be transmitted

is about 15,000, which is still a desirable

two up the pressure and a factor of such a potential

that the insulation of the machine will not be

to handle nor will the generator be forced to carry

excessive current.

It having been decided in the first place

investigation that will be the subject of the next

the next step is the design of the machine. The

conditions which govern the design of the machine

are, first, the power and the frequency of the

at least four times, a greater number being of course

necessary when the output of the plant is at least

Hydro-Electric Power Station Design

that four units of the largest commercial size will not carry the load.

We now have the frequency and capacity of the generators and desire to know the speed at which they will operate. This speed is limited to certain definite values by the limitation to constant frequency so that the r.p.m. must satisfy the relation:

$$60 f / p = n$$

where p is the number of pairs of poles and f the frequency. From this relation the following table may be made showing the number of poles for each speed to give the desired frequency and the catalogs of the manufacturers may then be consulted to determine the machine to use. Before settling upon a unit the peripheral velocity of the rotating parts should be calculated in order to ascertain if this value is too high for the safe operation of the machine. If this is the case it will be necessary to choose a machine with a greater number of poles and a slower speed.

that four times of the largest commercial size will not carry the load.

We now have the frequency and capacity of the

generator and we are to know the speed at which

they will operate. This speed is limited to certain

definite values by the limitations to convert frequency

as that the P.M. and actually the relation:

$$n = \frac{60}{p} \times f$$

where p is the number of pairs of poles and f the

frequency. From this relation the following table

may be made showing the number of poles for each

speed to give the desired frequency and the constant

of the generator may then be calculated to be-

termine the machine to use. Before setting down

and the rotational velocity of the rotating parts

should be calculated in order to ascertain if this

value is too high for the safe operation of the

machine. If this is the case it will be necessary

to choose a machine with a greater number of poles

and a lower speed.

Hydro-Electric Power Station Design.

The generators should if possible be direct-connected to the prime movers to eliminate any friction losses in the transmission and this fact necessitates a consideration of the speed of the wheels. This speed is determined by the effective head, and in the case of the Pelton wheel it was shown that the diameter of the wheel could be varied within certain limits to compensate for any disagreement between these two speeds. In the case of the turbine, however, this compensation is not always possible, although the manufacturers have in stock a great variety of wheels which will generally give the desired relation. If this cannot be obtained it will be necessary to gear the wheels and the generator can then be made to run at any speed, the desired frequency being obtained by the ratio of the gears.

Exciters:—From two to three percent of the output of the plant is required for the excitation of the units, so that this much must be added for

The following table shows the results of the work done during the year.

Table 1. Results of the work done during the year.

The following table shows the results of the work done during the year. It is divided into two parts, the first showing the results of the work done during the year, and the second showing the results of the work done during the year.

The first part of the table shows the results of the work done during the year. It is divided into two columns, the first showing the number of cases, and the second showing the number of deaths. The results are as follows:

Table 2. Results of the work done during the year.

The second part of the table shows the results of the work done during the year. It is divided into two columns, the first showing the number of cases, and the second showing the number of deaths. The results are as follows:

Table 3. Results of the work done during the year.

The following table shows the results of the work done during the year. It is divided into two parts, the first showing the results of the work done during the year, and the second showing the results of the work done during the year.

Hydro-Electric Power Station Design.

the gross output of the plant if the initial calculations are sufficiently close to warrant consideration of quantities of this magnitude. The exciter plant is the weak link in the system and great care must be exercised in the installation of the units. Several facts may be noted in this connection.

1. There should be two independent sources of excitation which may be readily interchanged so that in the event of one becoming disabled the operation of the system may not be suspended for any considerable period.

2. The prime movers or other apparatus driving the exciters should also be independent and capable of operating in parallel so that in the event of the failure of one system the other may be automatically thrown into service without the delay incident to the manual operation of the necessary switches. By this is meant that the exciters should be provided with reverse current

the gross output of the plant is the total output of the plant and is sufficiently close to gross output for the purpose of this calculation. The exciter plant is the weak link in the system and great care must be exercised in the installation of the exciter. Several factors may be noted in this connection.

1. There should be two independent sources of excitation which may be readily interchanged so that in the event of one becoming disabled the operation of the system may not be interrupted for any considerable period.

2. The prime mover or other excitation plant in the exciter should also be independent and capable of operating in manual so that in the event of the failure of one system the other may be automatically thrown into service without the delay incident to the manual operation of the exciter system. By this is meant that the exciter should be provided with a manual control

Hydro-Electric Power Station Design

relays so that in case one of the prime movers fails and the generator thereby becomes motorized the other may pick up the load while the first is automatically cut off from the exciter bus. This means that each system must be capable of carrying all the excitation necessary for the plant at any time, and since the breakdown of apparatus usually occurs at times of heaviest load, this consideration is of fundamental importance. In water-power stations the sources of power may be water-driven wheels for the operation of one system and motors for the other. In this case the motor-driven apparatus must be kept constantly in operation, since if this were not the case the failure of the water-driven exciters would disable the plant. At times of light load, however, it will be safe to operate the plant with but one set of exciters, since the possibility of the break-down of apparatus is slight and more is to be feared from the mistakes of the

relays so that in case one of the prime movers fails and the generator thereby becomes overloaded the other may pick up the load while the first is automatically cut off from the excitation bus. This means that each system must be capable of carrying all the excitation necessary for the plant at any time, and since the possibility of generator failure occurs at times of heaviest load, this consideration is of fundamental importance. In water-power stations the amount of power can be varied by changing the speed of the operation of the gates and valves for the water. In this case the water-turbine generator must be kept constantly in operation, since if this were not the case the falling of the water-driven excitation would be a disaster. At times of light load, however, it will be easy to connect the plant with one set of excitation, since the possibility of the loss of one of the generators is slight and there is no danger from the operation of the

Hydro-Electric Power Station Design

operators than from faults of the machines.

Transformers:—It having been decided that there will be a definite number of phases—usually three—and the transmission voltage being known, the transformer problem becomes simply a choice between the adoption of three single-phase transformers connected up to give the desired relation of e.m.f.'s or one three-phase transformer for each unit. The conditions influencing the choice are as follows:

1. The distance from the nearest shipping point to the power station—this enters in because of the fact that large transformers are more difficult to handle than small ones, and if, as is usually the case, the power house is located in a mountainous country, the smaller units would probably be chosen, since the cost of transportation will overbalance any saving in first cost.

2. The facilities for the handling of the apparatus at the power station, such as cranes, labor, etc. The use of the larger units of course

operators from limits of the machine.

Transformer:—It having been decided that there will be a definite number of phases—usually three—and the transmission voltage is known, the transformer problem becomes simply a choice between the adoption of three single-phase transformers connected up to give the desired voltage of 110 kV or one three-phase transformer for each unit. The conditions influencing the choice are as follows:

1. The distance from the nearest substation point to the power station—this distance is measured in miles and the fact that large transformers are more difficult to handle than small ones, and it is as a rule, the case, the power house is located in a mountainous country, the smaller units would probably be chosen, since the cost of transportation will be less and saving in time cost.

2. The facilities for the handling of the material at the power station, such as cranes, labor, etc. The use of an overhead line of three

Hydro-Electric Power Station Design

makes necessary a larger crane.

3. The necessity for a spare unit. In the case of three single phase units the connection may be so made that any one of the transformers in the station may be disconnected if injured and the spare put in its place by means of air-break disconnecting switches. If three units are employed a three phase unit may be used as a spare and the increased cost would make an installation of the single phase units desirable. This consideration vanishes when the size of the station is great or the units numerous, since the additional complication of circuits due to the installation of disconnecting switches more than balances the extra cost of the three phase unit.

4. If one of the single phase units becomes burned out it may be removed, but in the other case the whole transformer will need to be removed unless it is connected delta and allowed to operate with a V-connection at 58% of its former output.

needed necessary, a three phase.

3. The necessary for a three phase.

One of three phase units within the station
may be made that any one of the transformers in
the station may be disconnected at a time and the
station may be made of the three phase dis-
connected at a time. It is then with the station
a three phase unit may be used as a three phase unit
increased cost would make an installation of the
single phase units. This installation
various when the size of the station is great or
the unit's number, since the additional cost of
station of three phase to the installation of
disconnecting unit's more than balanced the extra
cost of the three phase unit.

4. If one of the single phase units is
burned out it may be removed, but in the other
case the whole transformer will need to be removed
unless it is connected with and allowed to operate
with a V-connection at 68% of its former output.

Hydro-Electric Power Station Design

The large units are in general desirable if the objections mentioned above do not operate, for they are more compact, all the coils in one case and the installation is less complicated, also the first cost is less. A disadvantage is, that since the surface of a transformer and its output do not vary uniformly, but the surface less rapidly, the cooling of the larger sizes will be a more serious problem. This however may be accomplished quite readily by the use of fans for circulating the air through the coils.

Instruments and Wiring:— These switchboards may be separated into two parts, the exciter board and the mainboard, and these may be concentrated in one position or separated, according to the size of the station. When the size is sufficient to warrant the constant attention of two operators, the exciter board may be isolated and located near the exciter units, the other being placed in a gallery. When this arrangement is adopted one operator may take charge of the exciter board and look after the units on the main floor while the

Hydro-Windmill Power Station Design

The large windmill and its general design - it

the optimum mentioned above is not correct;

for that and some others, all the units in one

case and the installation is also complicated, also

the first cost is low. A disadvantage is that

along the surface of a windmill, and the units

is not very uniform, but the surface is not uniform,

the cooling of the larger units will be a little more

from the wind. This however can be compensated

quite easily by the use of wind for circulating

the air through the cooling.

Installation and Windmill - These windmills

may be separated into two types, the smaller form

and the larger, and these may be connected

in one position or separated, according to the size

of the station. The two are in fact identical

except the constant rotation of two or three

the smaller form may be located in one place and

the smaller units, the other being in a

station. When this arrangement is adopted one or

erator may take charge of the smaller form and

look after the units on the main floor while the

Hydro-Electric Power Station Design

other confines his attention entirely to the operation of the lines and units. Where the plant is used to supply a large number of lines it is preferable to have the oil switches located in a room by themselves with an attendant there to unlock them, preparatory to their closing, at a signal from the operator in the gallery. This eliminates the danger of closing a dead machine on the line or other machine by mistake.

This segregating of switchboards and switches makes a more expensive construction and where the first cost is an item, or where the plant is small, the switchboards should be concentrated. In hydro-electric plants, where the lines are in general long ones, and this fact precludes the possibility of a large number of them, the operation of the lines will not be necessary more than perhaps once a day, so that the above mentioned precautions need not be taken in their operation.

The following instruments should be located on the main switchboard: For each generator panel,

Other conditions his attention directed to the operation of the lines and water. When required to use to supply a large number of lines it is necessary to have the oil which is located in a room by themselves with all equipment there to assist them, preparatory to their operation, at a stage from the operation in the gallery. When operation the danger of closing a line within on the line or other machine by mistake.

This suggestion of withdrawal and withdrawal, which is more extensive construction and where the first case is evident, or where the plant is small, the withdrawal should be considered. In places electric plants, where the lines are in general long ones, and the first procedure is a possibility of a large number of lines, the operation of the lines will not be necessary and the lines should be kept, so that the above mentioned procedure need not be taken in their operation.

The following statement should be located on the main withdrawal for each section plant,

Hydro-Electric Power Station Design

three ammeters, three indicating wattmeters, one voltmeter with selector switch for each phase, one integrating wattmeter, and one field ammeter.

The switches and auxiliary apparatus should comprise: An oil switch control for throwing the machine to H.T. bus, generator field switches, and a field rheostat control. The field switches should be equipped with a clip for short-circuiting the generator fields through a resistance when the switch is opened, thus avoiding the introduction of stresses into the windings by the induction of a high potential at that time.

The exciter equipment should consist of an ammeter and voltmeter for each unit, switches for throwing the exciter to the exciter bus, field rheostats for the voltage regulation, and the necessary equipment for the operation of the prime mover. If this is a motor there should be an integrating wattmeter to register the power consumed in excitation. Equalizers should also be installed if the exciters are compound wound and designed to operate in parallel.

Hydro-Electric Power Station Design

On the high tension side there should be overload relays on each phase, actuated from series transformers and esigned to open the generator switch at any desired overload and after any desired interval. These should be of the bellows type.

In the station some kind of frequencylimiting device is necessary to trip out the machines should they have a tendency to race beyond control. This may be of the inductive balance type or purely mechanical, and a common practice is to design the instrument so that it will operate at a frequency ten percent above normal. This values seems somewhat low for isolated plants, and fifteen percent would appear to be better.

Governors actuated by an electrical connection with the load ammeters have been suggested in order to eliminate the time necessary for the system to change in speed, but the idea has not as yet been tried, and seems not to fand favor with the designers of these plants.

Page
45

On the first day of the trial, the jury was told that the defendant was a "person of good character" and that the victim was a "person of bad character".

load relay in each phase, and after the relay is
transferred and after the relay is
at any further overload and after the relay is
transferred, those shall be the below two.

In the design of the present study, it was found that the device is necessary to bring out the features which they have a tendency to keep beyond control. This may be of the turn-of-the-balance type or merely self-balancing, and a further question as to whether the instrument so that it will operate at a frequency of about 100 cycles per second. The value of the low for isolated plants, and the effect of the

...to be better.

Government or caused by an official opposition
with the local authorities have been presented in order
to eliminate the time necessary for the transfer to
other in effect, but the idea has not yet been
tried, and seems not to think that with the decisions
of these rights.

Contents

The Malad River, Idaho, is a tributary of the Snake River, and is one of the most important sources of water for irrigation in the State. The river is about 100 miles long, and has a catchment area of about 1,000 square miles. The water is used for irrigation, and also for power. The river is a valuable asset to the State, and it is important that it be properly managed.

Part II.

Part II.

**Design for Proposed Hydro-
Electric Power Generating Station,
Malad River, Idaho.**

The proposed hydro-electric power generating station is located on the Malad River, about 10 miles from the mouth of the river. The station is designed to generate 10,000 horsepower, and to supply power to the State. The station is a valuable asset to the State, and it is important that it be properly managed.

Hydro-Electric Plant,-- Malad River, Idaho

Introduction.

In undertaking the actual design of a hydro-electric power plant, it was desired to have as near working conditions as possible. The selection of the location on the Malad River, Idaho was made after data had been secured which gave the exact conditions that existed at this point.

The General Problem.

The source of the power for the proposed plant is from the Malad River - a tributary of the Snake River: the two meeting in the western part of Lincoln county, which is located in the south-central part of the state of Idaho.

The present market for power from this source is that offered by the city of Boise - for light and power- a hundred miles distant: the town of Glens Ferry - principally for light - thirty miles distant: and locally, within a radius of from five to ten miles - for irrigation pumping purposes. A possible future market consists in certain rail-

Introduction.

The following is a brief description of a hydro-
electric power plant. It was designed to have an
easy working conditions in operation. The water-
flow is the location on the Milled River, Idaho was
made after data had been secured which gave the
exact conditions that existed at this point.

The General Problem.

The source of the power for the proposed plant
is from the Milled River -- a tributary of the Snake
River; the river is the western part of Idaho.
The river, which is located in the south-western
part of the state of Idaho.

The present water flow from this source

is that obtained by the city of Boise -- for light

and power -- a limited water supply: the flow of

about 1000 -- approximately 1000 -- 1000 miles

down: the flow, which is a result of from the

to the river -- for irrigation purposes for some

A possible future market existed in the state, which

Hydro-Electric Plant,- Malad River, Idaho

road electrifications that have been proposed in the vicinity.

No continuous record is available on the flow of the Malad River, but from such readings as have been taken of this quantity, it is evident that there is a uniform volume of water in the stream highly sufficient to carry a plant of 4800 kw. - such as is here proposed. This allows for the diversion of small quantities of water for irrigation purposes, these being protected by existing water rights.

The Water Supply.

The Malad River is supposed to be the outlet for both the Big Wood and the Little Wood Rivers. These latter rise on the southern slopes of the Tetan Mountains which form a water shed extending along the northern boundary of Blaine county, Idaho. From here the rivers flow southward, fed by numerous smaller streams,- a distance of some hundred and fifty miles. At this point they join, disappearing

most elevated section of the river valley in the

vicinity.

No one/land passed is situated on the river

of the Great River, but from each reading at the

bottom of this gradient, it is evident that

there is a uniform volume of water in the stream

highly sufficient to carry a load of 4000 ft. -

such as is now proposed. This shows the

volume of small quantities of water for irrigation

purposes, there being no doubt of the existing water

supply.

The Great River.

The Great River is known to be the

for both the Big Bend and the Great Bend Rivers.

These latter rivers on the southern slopes of the Texas

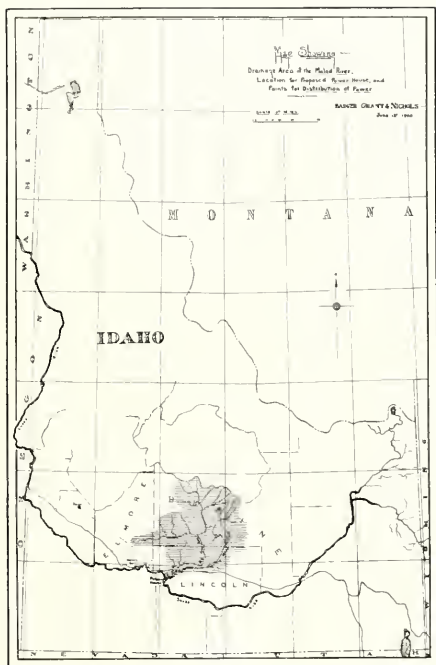
Mountains, which form a water shed extending along

the northern boundary of the country, Texas, form

here the rivers that southward, but by means of

smaller streams, - a distance of some hundred and

thirty miles. At this point they meet, discharging



Hydro-Electric Plant,- Malad River, Idaho

from the surface of the earth. Ten miles farther on the Malad River rises - being the accumulated waters of thousands of springs. The theory being that the two rivers - the Big Wood and the Little Wood - after leaving the surface, traverse a subterranean passage which terminates under the springs which form the nucleus of the Malad River. The water of the Malad is a constant in temperature almost throughout the entire year, this being at about 60° Fh. The course of the stream, from the springs that form its source, lies through a box canyon about three miles in length - to the south west, where the Malad empties its waters into the Snake River.

The drainage area of the Big Wood and Little Wood Rivers constitutes what is known as the "Big Camas Prairie", which lies chiefly in Blaine and Lincoln counties. The rainfall over this area is fairly uniform in its distribution. The walls of the box canyon through which the Malad flows are composed of lava and basalt rock. For a short dis-

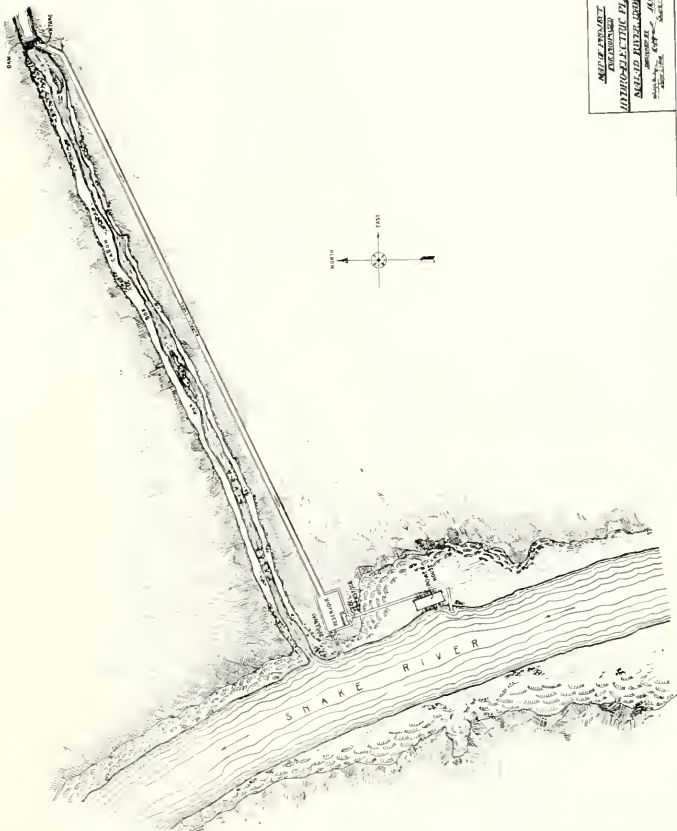
from the mouth of the river. The river is
on the Mole River - being the same
waters of the river. The river being
near the two rivers - the river and the river
good - after leaving the river, the river is
the river which is the river.

from the mouth of the Mole River. The
water of the river is a constant in temperature
almost throughout the entire year, this being at
about 50° F. The course of the river, from the
springs that are the source, the river is
canyon about three miles long - to the south
west, where the river is the river into the
Mole River.

The drainage area of the river and the river
and the river is the river as the "Mole
River", which is the river in the river and
the river. The river is the river in the river
the river in the river. The river is the river
the river in the river. The river is the river
the river in the river. The river is the river

SNAKE RIVER
 AND
 LUTHERAN CHURCH
 SNAKE RIVER, IDAHO
 1907
 1:50,000
 1:50,000

6



Hydro-Electric Plant,- Malad River, Idaho

tance its banks are covered with volcanic dust over which there is a sparse growth of sage brush.

The General Lay-out.

A reference to the "Map of Project", shown in the second illustration, will give an idea of the general lay-out as designed. At a point, a mile and a quarter from its junction with the Snake River, a dam is to be constructed across the Malad. An intake located here leads into an open channel through which the water is conveyed to a reservoir, from which it falls to the power house through a circular steel penstock. A spillway is located at the reservoir - for discharge into the Snake River direct. A controlling gate is located at the head of the penstock.

Power House.

The power house is to be located on the bank of the Snake River. In construction it is to be two stories in height, of concrete throughout. The foundations consist of layers of concrete resting

Figure 11 - Plan of the River, 1940

The river is a small stream with a bed of gravel and sand. It is a typical stream of the region.

The general layout.

A reference to the "Plan of Project" shows the

the second illustration, will give an idea of the

general layout as designed. At a point a mile

and a quarter from its junction with the Snake

River, a dam is to be constructed across the field.

At this point the river is to be dammed.

Through which the water is conveyed to a reservoir.

from which it falls to the lower house through a

vertical steel penstock. A spiral staircase is located

at the reservoir - for discharge into the Snake

River direct. A controlling gate is located at

the head of the penstock.

Power House.

The power house is to be located on the bank

of the Snake River. It consists of a concrete

two stories in height, of concrete construction. The

foundations consist of layers of concrete masonry

Hydro-Electric Plant,- Malad River, Idaho

on bed rock.

Equipment.

Water-wheels, unlike electrical apparatus, are not rated to carry any overload, so that any that is necessary to allow the shutting down of one of the units must be provided by installing wheels of the maximum capacity to be obtained at any time. The capacity of the station being 4800 kw., the installation will therefore be of four 2000 H.P. wheels, thus allowing an overload capacity of the desired amount. After considering the various types of wheels it was decided to adopt the type manufactured by the James Leffel Company. These are of the horizontal type, direct-connected, and are especially designed for the head considered- 185 feet. The efficiency at full load is found to be 86%, at three-fourths load 82%, and at half load 75%. The maximum efficiency is therefore obtained at the output of the apparatus which corresponds to full load on the generators, and any overload will somewhat lower the efficiency.

on bed rock.

Efficiency.

Water-wheel, with electrical generator.

are not rated to carry the overload, as that may

that is necessary to allow the water to run down at

one of the units must be provided by installing

wheels of the same capacity as the existing one

any time. The capacity of the station being 4000

hp., the installation will therefore be of 4000

2000 H.P. wheels, this allowing an overload cap-

acity of the design. After considering the

various types of wheels it was decided to select

the type recommended by the James Watson company.

These are of the horizontal type, direct-connected,

and are especially designed for the best consideration

the best. The efficiency of this load is found

to be 80% at three-fourths load, 85% and at full

load 90%. The maximum efficiency is therefore 90%

which is the result of the question which certain

bonds to full load on the generator, and the over-

load will therefore lower the efficiency.

Hydro-Electric Plant,-- Malad River, Idaho

The dimensions over all are eighteen feet by seven feet. eight inches, the diameter of the intake sixty inches, and of each of the two draft tubes - at the lower end - forty-eight inches, and at the outlet - thirty-two inches. Details of these wheels are shown on Drawing No. VIII.

Due to the peculiar advantages of the ground lay-out it is decided to bring the water into the power house overhead, by means of the large pipes shown in the drawings. These derive their power from the main penstocks, which is eleven feet in diameter at the outer end and narrows down to five feet for the last unit.

The governors used are of the standard type B - Lombard, and are purchased with the turbines. These operate by means of a mechanical connection with the units instead of by means of an electrical connection with the ammeters, as has been suggested in the first part of this paper. The estimated loss of time in their operation is approximately one second and is due to the large amount of inertia of the rotating parts. Further loss of time is eliminated

The dimensions over all are slightly less by seven feet, eight inches, the diameter of the shafts being sixty inches, and of each of the two shafts - at the lower end - forty-eight inches, and at the outlet - a thirty-two inches. Details of shape wheels are shown on Drawing No. 1111.

Due to the peculiar construction of the turbine lay-out it is decided to bring the water into the lower house overhead, by means of the large pipes shown in the drawings. These receive their power from the main penstock, which is eleven feet in diameter at the outlet and has a length of five feet for the last unit.

The governors used are of the standard type B - Howard, and are connected with the turbine. These operate by means of a mechanical connection with

the units instead of by means of an electrical connection as has been suggested in the first part of this report. The estimated loss of

time in their operation is approximately one second and is due to the large amount of water in the rotating parts. Further loss of time is eliminated

Hydro-Electric Plant,- Malad River, Idaho

by the installation of a reservoir near the station of sufficient capacity that the water level will never fall appreciably when a sudden demand is made for power. The time taken for the pulse to reach the station from the dam will be the distance divided by the velocity of sound in water.

Choice of generators is largely a matter of person's opinion, since the output of the large manufacturing companies is of a high degree of excellence. Due to the restrictions on the frequency noted above, this figure was taken at twenty-five cycles. The speed is therefore limited to the values given in the first part of this treatment under the head of Electrical Units. The values are, 300, 375, 750, etc. Since direct-connection with the water wheels is desired, the speed which was decided upon was 375 r.p.m. in order to conform in speed with the water wheels selected. This is a standard machine for the capacity wanted - 1200 kw. - so that no trouble was experienced due to too high

by the installation of a new water level and the
of sufficient capacity for the water level well
never felt especially near a sudden change in water
for power. The time taken for the water to reach
the station from the dam will be the distance divided
by the velocity of sound in water.

Choice of resonator is largely a matter of

personal opinion, since the nature of the water
manifesting properties is in a high degree of

elasticity. The in the construction of the resonator

noted above, the water was taken at twenty-five

cycles. The speed is therefore limited to two miles

when in the first part of this treatment water

the part is electrical units. The water level, 1904

WYKO, 1904, etc. Since direct-connection with the

water was in a direct, the water which was tested

from the WYKO, etc. in order to compare in water

with the water vessel selected. This is a standard

machine for the capacity water - 1904, etc.

no such as the water was experienced due to

Hydro-Electric Plant,-- Malad River, Idaho

a peripheral speed.

The transmission distance (maximum) is one hundred miles, so that there will be the necessity of stepping up the voltage for transmission, and the pressure of the machine is immaterial within wide limits. This figure was taken at 11,000 volts for the following reasons: Part of the power is to be transmitted a distance of thirty miles and it is desireable not to retransform this power from the extremely high voltage for the longer transmission. The machines are therefore connected directly to a "low tension" bus, at a pressure of 11,000 volts and the power for the shorter transmission is taken from this bus, while the transformers are fed from the 11,000 volt bus and transform the pressure from that to the value required for the longer distance.

Since the rough approximation for the transmission voltage demands a pressure of 100,000 volts,

Electro-Static Field, - Helix, Helix

a vertical field.

The transmission distance (distance) is the
distance, as far as there will be the possibility
of stepping up the voltage for transmission, and
the distance of the line is determined within
this limit. This figure was taken as 11,000 volts
for the following reasons: Part of the power is
to be transmitted a distance of thirty miles and
it is desirable not to retransmit the power from
the extremely high voltage for the longer trans-
mission. The distance and therefore conducted three-
ly to a "low voltage" and at a pressure of 11,000
volts and the power for the power transmission
taken from the line, while the transmission is
for from the 11,000 volt line and therefore the
pressure from that to the voltage required for the
longer distance.

Since the rough approximation for the trans-
mission voltage is a pressure of 11,000 volts,

Hydro-Electric Plant,-- Malad River, Idaho

and this is at present beyond the capacity of the insulators available, the voltage decided upon was 66,000, giving a value of volts per mile as 660, which is in accord with modern practice.

As was noted above, it is necessary to have two independent sources of excitation, and this is accomplished by means of the motor-and water-wheel driven units shown in the drawings. Greater dependence will be placed on the water-wheel-driven apparatus, so that two of them are installed and the motor-driven unit is to be used in emergencies, and to run in parallel with the others during the peak load or at times when a shut down would be most disastrous. Each of the exciter units are of 75 kw. capacity and the motors and water-wheels of 100 HP each. The power for the motor-driven exciter will be derived from a transformer fed from the "low tension" bus, the e.m.f. being stepped down from 11000 to 220 volts. The motor is of the induction type and is started by means of

Hydro-Union Electric Co. - Island Power, Idaho

and this is a constant factor in the operation of the
insulation system. The voltage between the two
88,000, giving a value of 176,000 volts.
which is in accord with normal practice.

As has been stated, it is necessary to have
two separate systems of excitation, and this is
accomplished by means of the motor and generator
driven motor system in the transformer.

Excitation will be taken on the water-wheel-
generator, so that the generator is installed and
the motor-generator will be in a position to
and to run in parallel with the other driving the

generator on at times when a short circuit is
most dangerous. In all the cases where the
is a generator and the motor and water-wheel
of 100 HP each. The power for the motor-generator

exciter will be derived from a transformer fed
from the "low tension" bus, the exciter being step-
fed from 11000 to 220 volts. The motor is
of the induction type and is started by means of

Hydro-Electric Plant,—Malad River, Idaho

the special starting taps shown diagrammatically in the wiring diagram. This dispenses with the necessity for auto-transformers, and the more expensive construction entailed. It will be necessary only to bring out two additional leads from the secondary of the transformer, and since this may be located at no great distance from the exciter, the expense will be small compared with that incident to the use of an auto-transformer.

By thus dividing the units there is no danger that the excitation of the fields will be lost at any time except under the most extraordinary conditions. These precautions are necessary due to the fact that the exciter system is the weakest part of the plant and the greatest care must be taken in its design if continuity of operation is expected.

The conditions influencing the use of single or three phase transformers were noted above. In this case it was decided to install single phase units due to the fact that the country is rough

[illegible]

the Special Committee on the subject of the
the first of these. This is the first of the
and the second, and the third, and the fourth,
expensive construction of the first. It will be ne-
cessary only to add the two additional levels
from the secondary of the first, and the
this may be found in the first of the first
existing, the expense will be small, and the
that incident to the first of the first.

that the situation of the world will be such that any kind of war will be most disadvantageous to all. These conditions are necessary and sufficient to bring about a new world order. The new world order is the result of the present state of the world and the present state of the world is the result of the present state of the world.

...the
... ..
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Hydro-Electric Plant,--Malad River, Idaho

and the distance to which they must be transported is rather large. It also makes necessary the installation of a comparatively cheap unit only, this being placed somewhere on the floor of the transformer room and connected in as desired by means of flexible leads.

The capacity of the transformers will be ten percent greater than that of the generators to conform with common practice, so that each unit must be rated at 440 kw. These are to be connected up delta on both sides. This is also an additional safeguard, since in this case if one of them becomes burned out, the other set can then carry 58% of the load with the same heating by operating on a V-connection, and, the continuity of the service need not be interrupted during the time necessary for the installation of the spare unit.

On account of the character of the load the operation of the lines will not be necessary more than once or twice a day and therefore attendance

WFO-11-0707 Plant-11-0707

[illegible][illegible]

On account of the character of the work, the operation of the plant will be necessary for some time, and it is expected that the plant will be in operation for some time.

Hydro-Electric Plant,--Malad River, Idaho

of an operator on the switches will not be necessary. These switches should be located, however, in another room to protect them from the dampness, and to insure their proximity to the high tension buses. For this reason they are to be located upstairs where they can be readily reached from the lower floor by the two stairways. The high tension buses are also located here so that a minimum amount of copper is required. The two buses run parallel throughout their length, as shown, and this makes it possible to extend the plant at any time by merely tearing out the end walls and installing a new unit. The buses can then be extended also and the station will then be symmetrical as before.

The drawings showing the arrangement of the above specified apparatus and machinery are reproduced in the following pages.

Hydro-Electric Plant,--Mississippi River, Idaho

of an operator in the switches will not be necessary. These switches should be located, however, in a central room in the building from the dam, and to insure their proximity to the dam, the dam should be located near the dam.

It is suggested that the dam be located near the dam.

The dam should be located near the dam.

The dam should be located near the dam.

The dam should be located near the dam.

The dam should be located near the dam.

The dam should be located near the dam.

The dam should be located near the dam.

The dam should be located near the dam.

The dam should be located near the dam.

before.

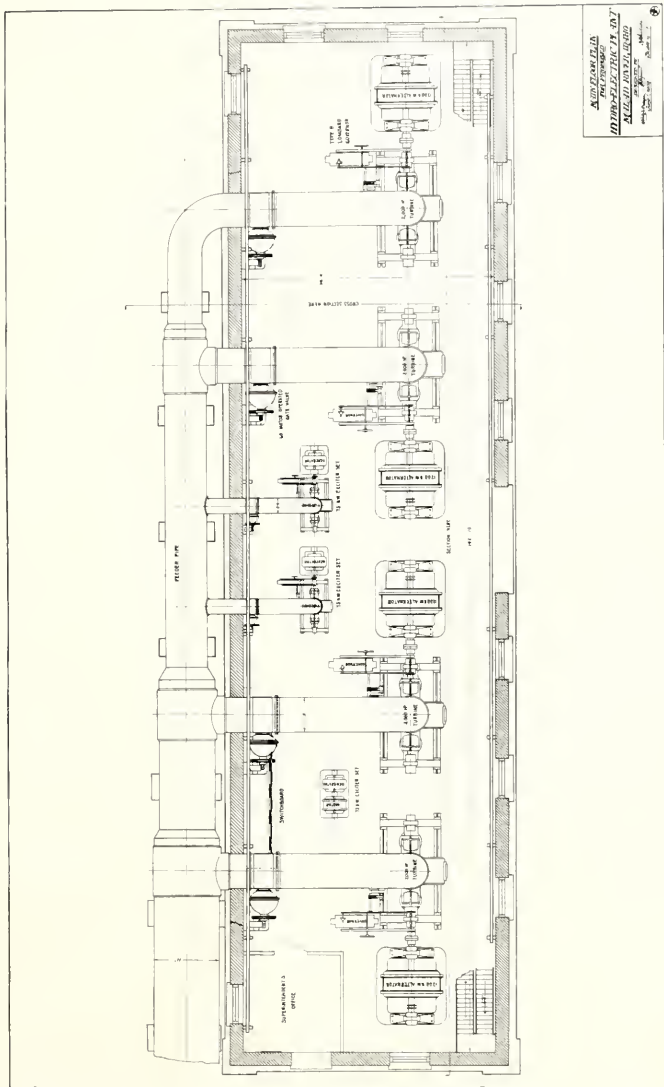
The dam should be located near the dam.

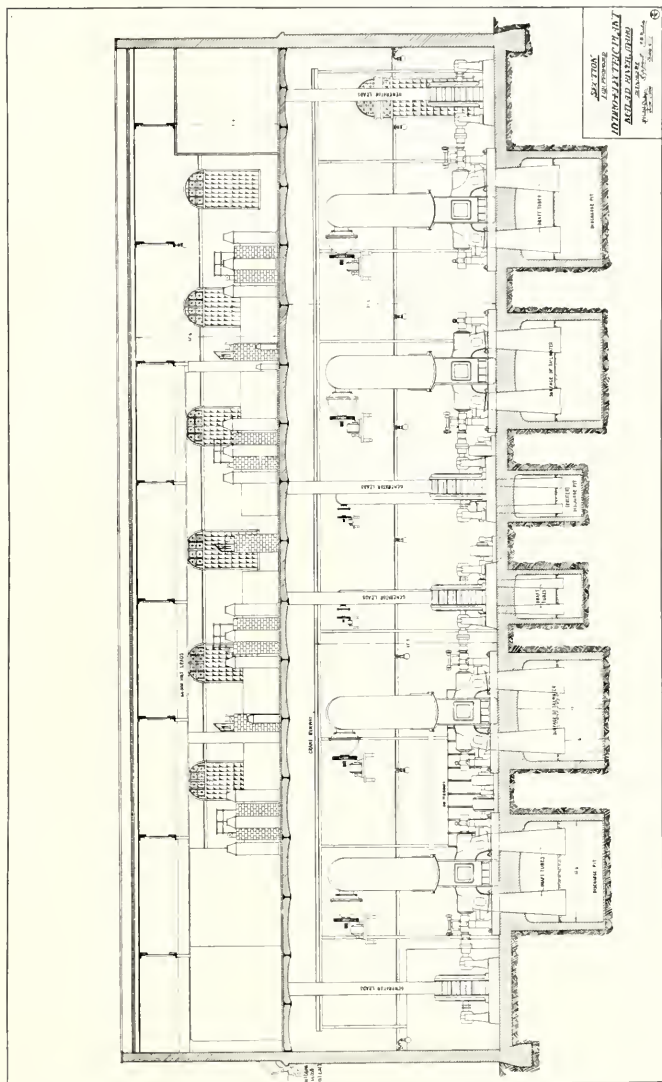
The dam should be located near the dam.

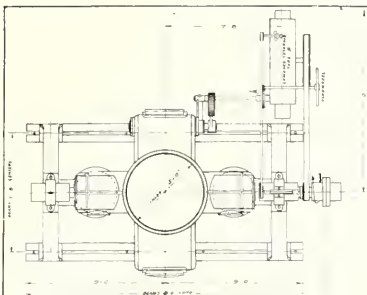
The dam should be located near the dam.

D R A W I N G S
for proposed
HYDRO-ELECTRIC POWER PLANT
Malad River,
Idaho.

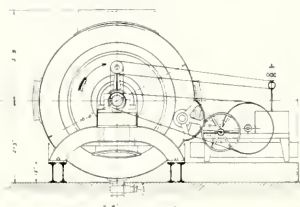
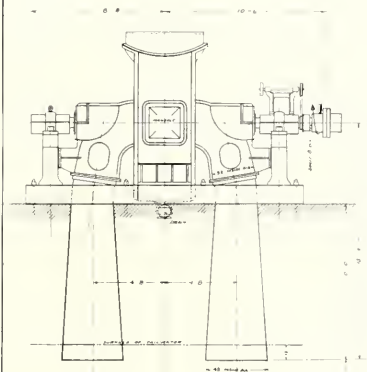
UNITED STATES
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF STAFF
WASHINGTON, D. C.
1917







100 INCH
 DOUBLE DISCHARGE HORIZONTAL TURBINE
 1000 HORSE POWER 200 RPM
 185 FEET HEAD
 1150 GALLONS WATER PER MINUTE



HYDRAULIC TURBINE
 FOR PURPOSES
 HYDRO-ELECTRIC PLANT
 ACQUEDUCT RIVER, U.S.A.
 MADE IN U.S.A.
 100 INCH

Hydro-Electric Plant—Malad River, Idaho.

Transmission of Power:—There are to be two 66000 volt three phase, twenty-five cycle transmission lines from the plant to Boise City and to Glenn's Ferry, Idaho. In addition there are two 11000 volt lines to supply power for public purposes in the vicinity of the plant. The calculations for the 66000 volt lines follow:

Boise City line, 100 miles long, 3200 kw. to be transmitted, transmission voltage, 66000

Line loss	256 kw.
Res. per wire	109 ohms,
Size of wire	# 3 Band S.
Distance between wires	6'--6"
Inductance per wire	.21 henrys
Capacity to neutral	1.36×10^{-8} f/mile
Natural frequency	470 cycles
Charging current	8.2 amp.
Ind. reactance	33 ohms
Cond. reactance	4670 "
Reg. no load	.374%

Hydro-Electric Plants—Mississippi River, 1900.

Transmission of Power:—There are 10 lines

80000 volt lines, 100 miles long, 100 miles long, 100 miles long.

also lines from the line to other cities and to

other cities, 100 miles long, 100 miles long, 100 miles long.

10000 volt lines for power to other cities and to

other cities, 100 miles long, 100 miles long, 100 miles long.

where the 80000 volt lines are:

St. Louis, 100 miles long, 100 miles long, 100 miles long.

to be transmitted, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

St. Louis, 100 miles long, 100 miles long, 100 miles long.

Hydro-Electric Plant, - Malad River, Idaho

Reg. full load	3.1 %
Reg. 85% power factor	4.3 %
Wt. copper	252,842 #
Spacing of poles	45/mile
Number of poles	4,500

Glenn's Ferry Line.

30 miles long, 800kw.

Transmission voltage	66,000
Line loss	1.8 %
Resistance per wire	97.5 ohms
Size of wire	# 8
Distance between wires	6' - 8"
Inductance per wire	.068 henrys
Capacity to neutral	.375 x 10 ⁻⁸ f/mile
Natural frequency	1,570
Charging current	2.25 amperes
Ind. reactance	10.6 ohms
Cond. reactance	17,000 ohms
Reg. full load	.05 %
Reg. 85% power factor	.08 %
Number of poles	1,350

Hydro-Electric Plant - White River, Idaho

3.12	Net full load
4.77	Net 25% power factor
200,000	Wt. copper
12,000	Spacing of poles
4,100	Number of poles

Glenn's Ferry Line

30 miles long, 8000	Transmission voltage
100,000	Line loss
1.8	Resistance per mile
20.5 ohms	Size of wire
30	Distance between poles
41 - "	Resistance per wire
1000 pounds	Capacity to support
3000 x 10 ⁴ lbs	Mechanical strength
1,000	Thermal expansion
10.0 ohms	Thermal expansion
17,000 ohms	and resistance
400	and resistance
100	Net full load
1,000	Net 25% power factor
1,000	Number of poles

APPENDIX.

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Hydro-Electric Power Station Design.

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Transmission of Water Power; Adams.

Design of a Dam for Electrical Engineering; Newell.

Water Power; or, The Development of Water Power.

Notes and Designs on Hydro-Electric Power Stations.

Hydro-Electric Power Stations; or, The Development of Water Power.

Location of Electric Power Stations.

Designs, 1881-1882.

Electricity from Water Power.

Elec. Eng., 24: 284.

Water Power from Turbines and Motors.

Eng. Mag., 1881: 282-283.

" " " 30: 71, 100.

Use of Water Power in the Development of

Electricity.

Eng. Mag., 1881: 282.

Electricity from Water Power, 1881-1882.

The Eng. Mag.

Water Power of the Loch Lomond.

Hydro-Electric Power Station Design

PRICES and COST ITEMS. (Malad River Project)

Hydraulic Turbine Units-

Including draft-tubes and type "B"
Lombard Governor. Gross weight about
75,00 pounds. F.O.B. cars at factory,
each -

\$ 7,800.00

Steel Penstock -

Circular in form: of riveted steel
plates, with necessary saddles and
stiffeners. Per lineal foot (about) -

\$ 45.00

Wooden stave pipe at about half
this figure.

Nearest railroad connection - at Bliss, Idaho (three
and one-half miles) : Oregon Short Line.

Freight rate to this point, from Chicago,
on electrical machinery about 1 1/2 cents
per pound. The rate on structural steel
from Pueblo to Bliss,- about 75 cents a
hundred.

Cement : about \$3.25 a bbl., f.o.b. Bliss.

Sand, rock and gravel to be had on the work.

Suitable poles for the transmission (thirty-
five to forty feet long) can be had on the
work for about \$5.00 per pole.

Hydraulic Power Station Test

Y H I O F A and C O E T E M A
(United River Project)

Hydraulic Turbine Unit

Including draft tubes and type "B"
downward flow type. Gross weight about
14,000 lbs. Net weight about 12,000 lbs.
and 10,000 lbs. net weight.

14,000 lbs.

Base Test

Base test is run at 100% of rated speed
with no load. The test is run at
100% of rated speed with no load.

14,000 lbs.

When the test is run at 100% of rated
speed the test is run at 100% of rated
speed.

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Hydro-Electric Power Station Design

Market for power -

Transmitted and distributed to
Boise - 100 miles,- 2-1/2 cents
a kw. hour.

To Glenns Ferry - 30 miles,-
5 cents a kw. hour.

For pumping purposes in vicinity
of plant,- 1-1/2 cents a kw. hour.

Transmission Lines.

To Boise (100 miles) -

Cost of copper	\$	37,296.00
" " poles		18,900.00
" " cross arms		3,150.00
" " insulators		23,625.00
" " pins		7,200.00
Total	\$	<u>90,171.00</u>

To Glenns Ferry (30 miles) -

Cost of copper	\$	3,566.00
" " poles		5,670.00
" " cross arms		945.00
" " insulators		7,088.00
" " pins		2,160.00
Total	\$	<u>19,429.00</u>

